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Matching Accessories: Standardization Developments in Electric Vehicle Infrastructure

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Abstract— The availability of charging infrastructure is one of the key issues to allow a wholesale deployment of electrically propelled vehicles (battery-electrics and plug-in hybrids). International standardization is essential in order to obtain safe and compatible solutions. This paper presents current developments in the field. *Copyright Form of EVS25***.**

Keywords— standardization, RCS, infrastructure, safety

1. Introduction

In urban traffic, due to their beneficial effect on environment, electric vehicles are an important factor for the improvement of traffic and more particularly for a healthier living environment. Electrically propelled vehicles make use of energy sources which need access to the electric supply network for recharging, and thus need suitable infrastructures. [1]

It is clear that international standardization will be a key element in making such development possible. This paper will thus report on current evolutions in the field. The international standardization and regulation work on these subjects is thus developing worldwide with a fast pace, with the main standardization work being performed by IEC TC69 (conductive charging), IEC SC23H (plugs and connectors) and the IEC TC69/ISO TC22 joint working group for vehicle to charging post communication.

The actors involved in the international standardization in the field are shown in Fig. 1.

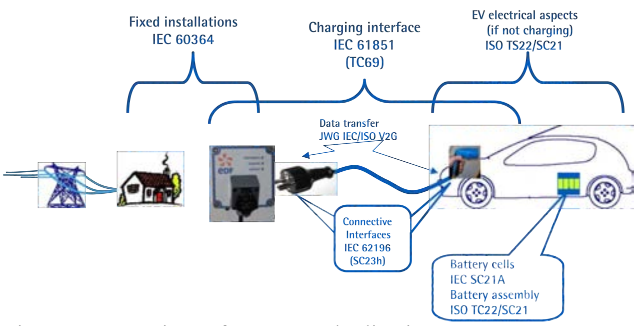

Figure 1: Committees for EV standardization

2. The Three Pillars of Standardization

The infrastructure standards being developed actually address the three main pillars of standardization – safety, compatibility and performance.

Safety shall be the paramount factor for every charging system, particularly taking into account that the charging will be done on the street involving non-specialist personnel. Significantly differing views exist on the acceptability of charging at non-dedicated power outlets, the so-called "Mode 1" charging. The interaction with national codes and regulations becomes a main issue in this context.

Compatibility fosters the adoption of common accessories (plugs and sockets) enabling vehicles to be charged everywhere. Regional differences concerning electricity distribution and safety regulations have led to the development of several potential solutions.

Performance in this context stands for optimizing charging performances through a "smart grid", allowing charger ampacity selection mandated by grid capacity, including the "vehicle to grid" operations where the power flow to the vehicle is reversed, as well as the charging and billing issues.

3. The Battle of the Modes

In order to present an easy classification, the international standard IEC 61851-1 [2] has defined several charging modes.

3.1 Mode 1 charging

Mode 1 charging refers to the connection of the electric vehicle to the a.c. supply network utilizing standard (domestic or industrial) socket outlets. At this time, Mode 1 charging is the most common option for electric vehicles.

However, a number of safety concerns must be taken into account. The safe operation of a Mode 1 charging point depends on the presence of suitable protections on the supply side: a fuse or circuit breaker to protect against overcurrent, a proper earthing connection, and a residual current device switching off the supply if a leakage current greater than a certain value (e.g., 30 mA) is detected. Without proper earthing, a hazardous situation for indirect contact could occur with a single earth fault within the vehicle.

In most countries, residual current devices (RCDs) are now prescribed for all new electric installations. However, still a lot of older installations are without RCD, and it is often difficult for the electric vehicle's user to know, when plugging in the vehicle, whether or not an RCD is present. Whereas some countries leave this responsibility to the user, Mode 1 has therefore been outlawed in a number of countries such as the United States, and restricted to private premises in other countries like Italy.

In countries where the use of Mode 1 charging is allowed, it will remain the most widespread charging mode for private premises (including residential garages as well as corporate parking lots) due to its simplicity and low investment cost. With a proper and up-to-date electrical installation, Mode 1 allows charging in full safety. Mode 1 charging can be compared to electric engine preheating systems, which are in common use in Nordic countries for many years without any safety problems.

However, the uncertainty faced by the user about the presence of an RCD when plugging in the electric vehicle in an arbitrary standard outlet results in a potential hazard. For this reason, vehicle manufacturers, because of liability issues and the risk for bad publicity tend to steer away from Mode 1 charging in the long term.

3.2 Mode 2 charging

Mode 2 charging connection of the electric vehicle to the a.c. supply network (mains) also makes use of standardized socket outlets. It provides however additional protection by adding an in-cable control box with a control pilot conductor (see below) between the electric vehicle and the plug or control box.

The introduction of Mode 2 charging was initially mainly aimed at the United States, and initially considered a transitional solution awaiting the development of dedicated infrastructure.

Recently however, Mode 2 has gained a renewed interest also in Europe, with the intent replacing Mode 1 for charging at nondedicated outlets.

Besides the obvious drawbacks of using an in-cable control device, the main disadvantage of Mode 2 is that the control box protects the downstream cable and the vehicle, but not the plug itself, whereas the plug is one of the components more liable to be damaged in use.

3.3 Mode 3 charging

Mode 3 charging involves the direct connection of the electric vehicle to the a.c. supply network utilizing dedicated electric vehicle supply equipment. The international standard IEC 61851-1 [2] mandates the "control pilot" device between the supply equipment and the electric vehicle, which has the following functions mandated by the standard:

- verification that the vehicle is properly connected
- continuous verification of the protective earth conductor integrity
- energization and deenergization of the system
- selection of the charging rate

The control pilot is typically implemented as an extra conductor in the charging cable assembly, in addition to the phase(s), neutral, and earth conductor. This necessitates the use of special dedicated accessories.

The pilot current is sent through the loop formed control pilot conductor and the earth conductor, through a resistor in the vehicle. The current returns to the charging post through the earth conductor. When the pilot current flows correctly, the contactor in the charging post is closed and the system is energized.

When no vehicle is connected to the socket outlet, the socket is dead. Power is delivered only when the plug is correctly inserted and the earth circuit is proved to be sound.

An overview of the principe scheme is found in Fig. 2. The ampacity control function is implemented in the new version of the standard 61851-1 [3] through the shape of the control pilot signal with the duty cycle defining the current that the charging point can deliver (Fig. 3).

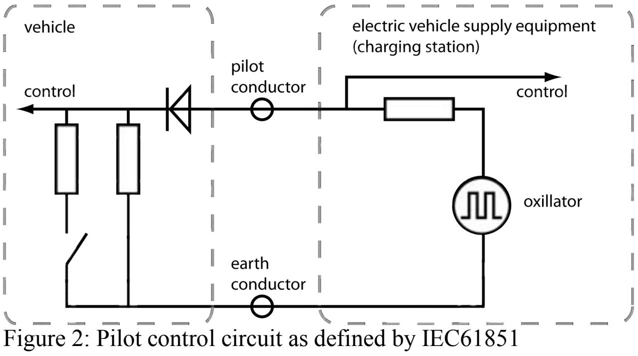

Figure 2: Pilot control circuit as defined by IEC61851

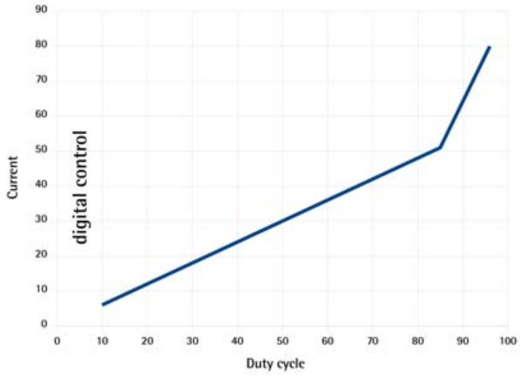

Figure 3: Pilot control ampacity (IEC 61851)

The new version of the standard allows alternative ways to obtain the control pilot functionality. One example is the use of power-line communication. An interesting implementation of the latter has been developed by Electricité de France [4]. The principle is illustrated in Fig. 4. The control pilot signal is a common-mode signal between the phase wires and the earth conductor, using a 110 kHz carrier frequency. Filter circuits are present to avoid the unwanted transmission of data signals from the charging system to the mains, and to be compliant with relevant standards and regulations [5].

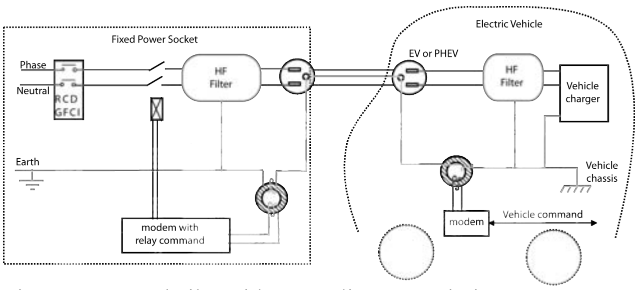

Figure 4: Control pilot with power line transmission

3.4 Mode 4 charging

Mode 4 charging is defined as the indirect connection of the electric vehicle to the a.c. supply network (mains) utilizing an off-board charger where the control pilot conductor extends to equipment permanently connected to the a.c. supply.

4. Communication issues

The communication between the vehicle and the charging post can be developed in several ways, with increasing sophistication. In Mode 1 or Mode 2 charging, where standard, nondedicated socket outlets are used, there is no communication at all. In Mode 3, there is the control pilot communication with the added option of ampacity control; Mode 4 d.c. charging (particularly used for fast charging) will in most cases need additional communication functions to allow battery management. This issue will be the subject of the standard IEC 61851-24 [6] on which work has started by the end of 2010.

The development of new concepts such as "smart grid" or "vehicle to grid" has created however the need for more advanced communication functions providing functionalities such as:

- vehicle identification and billing
- charge cost optimization
- grid load optimization
- peak-shaving functionalities (vehicle-to-grid)

The standardization of this is being addressed by a joint working group uniting ISO TC22 SC3 (electric equipment on road vehicles, including on-board communication systems), ISO TC22 SC21 (electric road vehicles), and IEC TC69 (electric road vehicles).

The new standard, ISO/IEC 15118 [7], will describe the communication, in terms of data format and message content, between the electric vehicle and the electric vehicle supply equipment (charging post), as well as message content and data structure to enable billing communication and grid management.

The communication protocols are based on the well-known seven-layer Open System Interconnection (OSI) reference model [8].

In order to define the implementation of the communication in the lower layers, it is first necessary to analyze the real communication needs and the information to be transferred by the different "actors" involved in the charging process. These actors include physical devices such as the charging post or the vehicle controller, entities such as electricity suppliers or grid operators, and last but not least the vehicle user. An overview of actors potentially involved and the communication links between them is shown in Fig. 5.

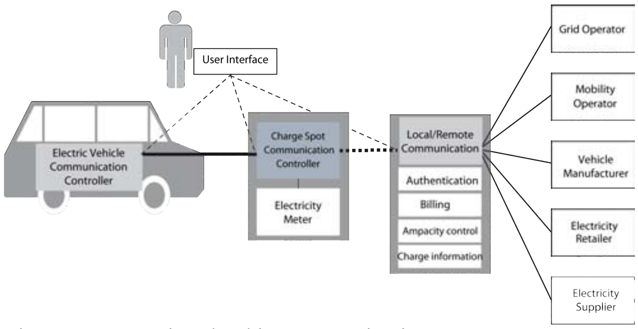

Figure 5: Actors involved in communication

The local or remote communication system may have the function of a "clearing house" for the authentication, collecting and consolidation of grid and billing parameters from the actors as well as transmitting charging process information to the respective actors. Not all such functions are necessarily required for the basic charging functions, and the system can thus become rather complex, with the danger of overstandardization lurking around the corner.

All charging processes are contextualized in so-called “use cases,” where three main categories can be discerned:

- charging with no communication: this is the classical Mode 1 or 2 charging, also Mode 3 charging with only the basic control pilot safety functions
- charging with minimal communication: Mode 3 charging with ampacity control to adapt to local physical limits or to perform dynamic grid optimization
- charging with maximum communication, including automatic billing and grid control and process information

The increasing functionalities are illustrated in Fig. 6.

The actual communication technique used can vary, with several solutions being experimented: RFID tags, pilot conductor or powerline communications, CAN-bus, wireless (Bluetooth or ZigBee), mobile phones, etc.

The use cases are then represented by scenarios describing the sequence of events when an user charges the vehicle.

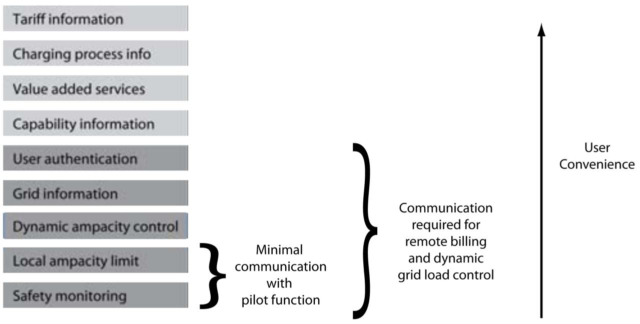

Figure 6: Increasing complexity of use cases

5. Choice of accessories

For Mode 1 or 2 charging, but also for Mode 3 charging with power-line communication, standard plugs and sockets can be used encompassing only phase, neutral, and earth contacts. In most areas, this will usually be the standard domestic plugs as described in various national standards, and typically rated 10–16 A [9].

One has to recognize however that these domestic plugs, particularly not the low-cost versions mostly used on consumer grade equipment, are not really suited for the heavy-duty operation of electric vehicle charging. This leads to a shorter lifetime of the accessories and to contact problems which may cause hazardous situations.

It is thus recommended to use industrial plugs and sockets such as the international standard IEC 60309-2 accessories [10]. These are widely used for industrial equipment but also for outdoor uses like camping sites, marinas, etc., where they function in an operation mode comparable to an electric vehicle charging station. Both plugs/sockets and connector/ inlets are available in the IEC 60309-2 family.

The use of a physical control pilot conductor however necessitates the introduction of specific accessories for electric vehicle use. Such plugs and sockets are described in the international standard IEC 62196 “Plugs, socket-outlets, vehicle couplers and vehicle inlets – Conductive charging of electric vehicles.”

Part 1 of this standard [11] gives general functional requirements; it is based on the general standard IEC 60309-1 [12], adapted with the requirements of IEC 61851-1 [2].

The second part of the standard, now under preparation, proposes several types of accessories, the (proposed) designs of which are illustrated in Fig. 7 [13].

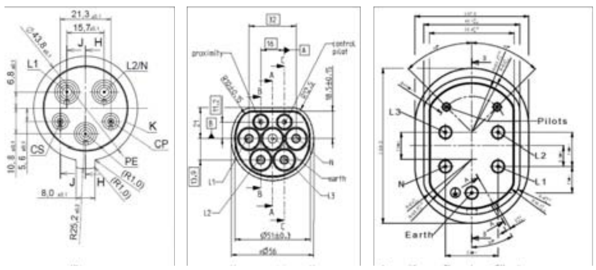

Figure 7: Proposed type 1, 2 and 3 accessories.

- Type 1: a plug rated for 250 V and 32 A single phase. It is fitted with two extra contacts: one for the control pilot (CP) and one for an auxiliary coupler contact (CS) which can be used to indicate the presence of the connector to the vehicle and to signal the correct insertion of the vehicle connector into the vehicle inlet.
- Type 2: a plug rated for 400 V three-phase, and up to 63A, also with two auxiliary contacts
- Type 3: a plug rated for 400 V three phase and 32A, also with two auxiliary contacts.

Type 1 corresponds to the proposal of SAE J1772; for applications in Europe however, where three-phase power distribution is more widespread, there was a demand for three phase accessories represented by types 2 and 3.

The choice between the types is not only influenced by commercial preferences but also by existing national regulations. In particular, some countries demand shutters to ensure IPXXD protection on all socket-outlets in domestic environments. Type 3 connector can accept shutters whileas Type 2 is not designed for them. The fact that in Mode 3 any socket-outlet is dead unless a vehicle is properly connected my obviate the need for shutters; for some however, the non-use of shutters is considered a retrograde step in the field of safety which may create a wrong impression on the public.

6. Conclusions and evolution

The charging of electric (and plug-in hybrid) vehicles is now a very hot issue in international standardization, with the main activities in the following committees:

- IEC TC69, working on the various parts of IEC61851, and restarting standardization work on inductive charging (IEC61980).
- IEC SC23H, working on accessories (IEC62196).
- The joint working group ISO TC22 SC3/ISO TC22 SC21, and IEC TC69, working on communication issues (ISO15118).

One of the main problems facing electric vehicle standardization work however has always been the collaboration between the electrotechnical world and automotive manufacturers. The electric vehicle is in fact a device which is both a road vehicle (dealt with by ISO committee) and an electrical appliance (dealt with by IEC committee), where the differences in standardization culture between the automotive and electrotechnical realms have always been difficult to overcome. For some periods in the past, communication between the respective ISO and IEC committees was quite limited, and a special steering group had to be set up. The recent developments in IEC TC69 however have witnessed a considerable influx of automotive experts in the IEC committee, which is somewhat of a historical precedent.

Furthermore, the European Union has been aware of the growing interest in the field and has commissionned the European standardization institutes, CEN and CENELEC, with constituting a focus group to coordinate European work in the field and the adoption of global standards. This focus group started is activities in various working parties in the summer of 2010

It has to be clear however that the electric aspects of the charging process have to be considered and that the vehicle, as appliance connected to the grid, has to behave properly and safely. The vehicle – driving – is to be considered the province of ISO, whileas aspects concerning the connection to the network or individual electric components are to be dealt with by IEC. This includes all charging accessories, where also local electric regulations will come into play.

The communication between the vehicle and the charging post only as part of the vehicle management system is dealt by a joint working group. The complexity of the issues approached here carries a clear risk of overstandardization which is to be avoided to come to a workable standard. The communication between the "smart" charging station and the "smart" grid is to be covered by appropriate international standards on smart grid.

Only this way will it be possible to realize unified solutions which will be a key factor in allowing the deployment of electrically propelled vehicles on a global level.

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8. Authors

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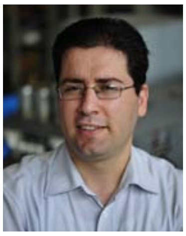

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